



# Characterization of a mid-latitude ice-rich landing site on Mars to enable in situ habitability studies

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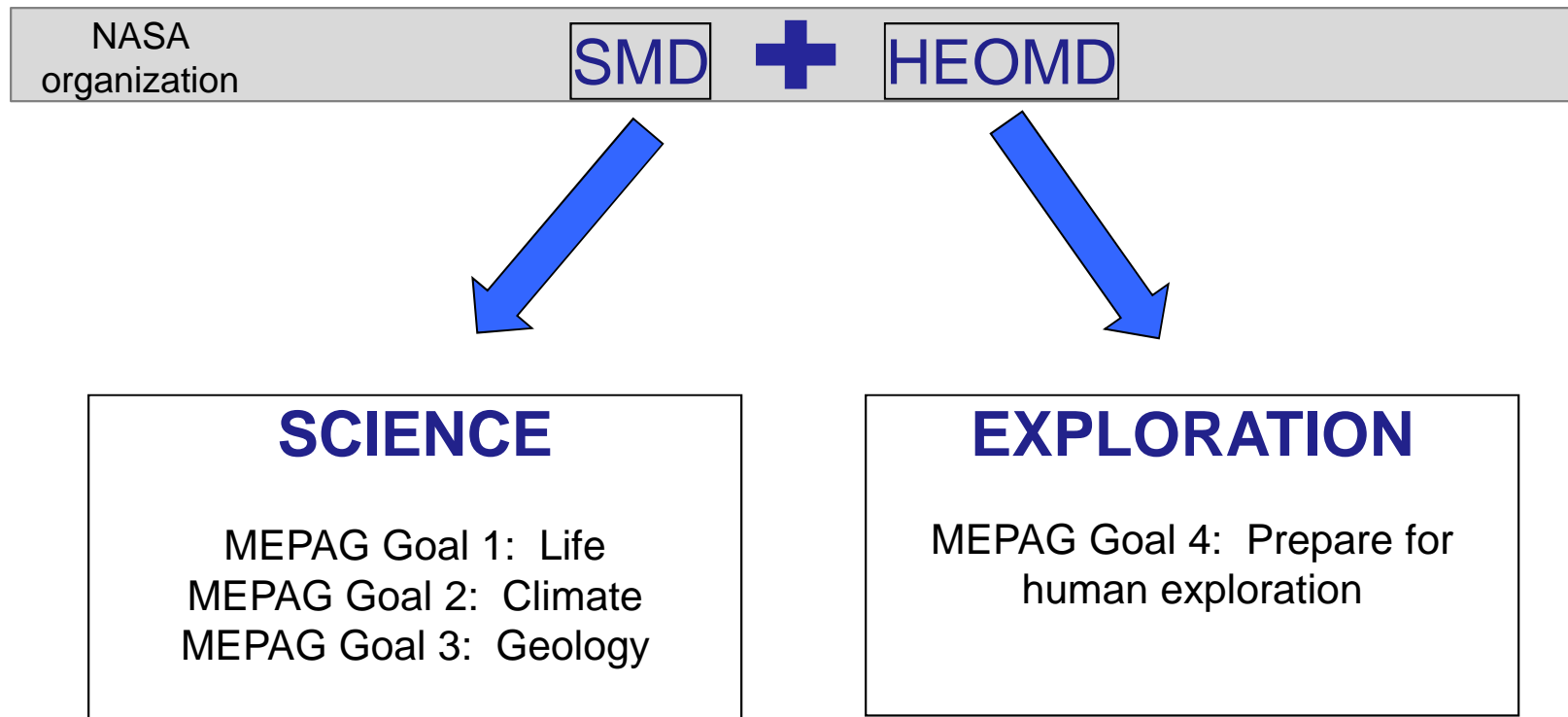
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# Mars Icebreaker Mission Concept

**Primary Motivation = Search for evidence of life on Mars**



*“Exploration enables science, and science enables exploration.”*



# Mars Icebreaker Mission Concept

**Primary Motivation = Search for evidence of life on Mars**

## Science Goals

1. Search for biomolecules that would be conclusive evidence of life.
2. Search for organic material in the ground ice.
3. Determine the processes of ground ice formation & the role of liquid water.
4. Understand the mechanical properties of Mars ice-cemented soil.
5. Assess the recent habitability of the environment with respect to required elements to support life, energy sources, and possible toxic elements.

## Nominal Payload

1. Drill (1 m depth)
2. Sample handling system
3. Signs of Life Detector (SOLID)
4. PHX wet chemistry lab (WCL)
5. APXS
6. Laser desorption mass spec
7. Camera system

## Spacecraft

Any – (almost) any ride to Mars will do.



SpaceX Red Dragon



LM PHX lander



# Access the Ice

## **Studies of the ice-rich subsurface on Mars are critical for several reasons:**

- 1) Protects organic and biogenic compounds from destruction by radiation
- 2) Ideal for long term preservation of organic and biologic molecules
- 3) Provides a source of H<sub>2</sub>O for biologic activity
- 4) Provides raw materials for ISRU to enable human exploration

## **Examination of subsurface Mars ice can test several hypotheses:**

- 1) Whether ground ice supports habitable conditions
- 2) That ground ice can preserve and accumulate organic compounds
- 3) That ice contains biomolecular evidence of past or present biological activity
- 4) That ice can serve as an in situ resource for human exploration



# Subsurface ice

**There are TWO locations on Mars with DIRECT observations of subsurface ice.**



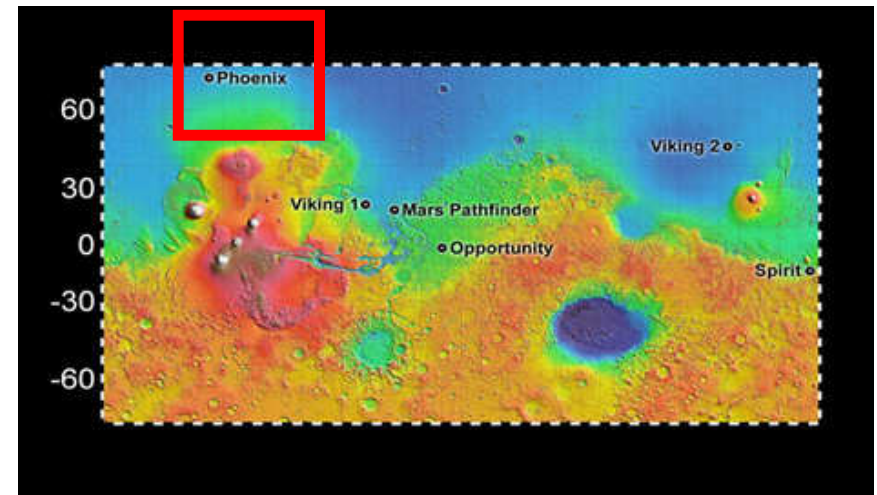
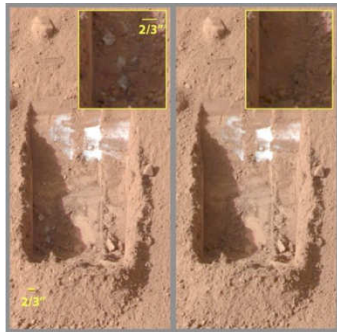
# Subsurface ice

There are **TWO** locations on Mars with **DIRECT** observations of subsurface ice.

## 1. Phoenix landing site.



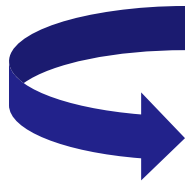
Not great for human exploration, though, due to winter CO<sub>2</sub> ice coverage.



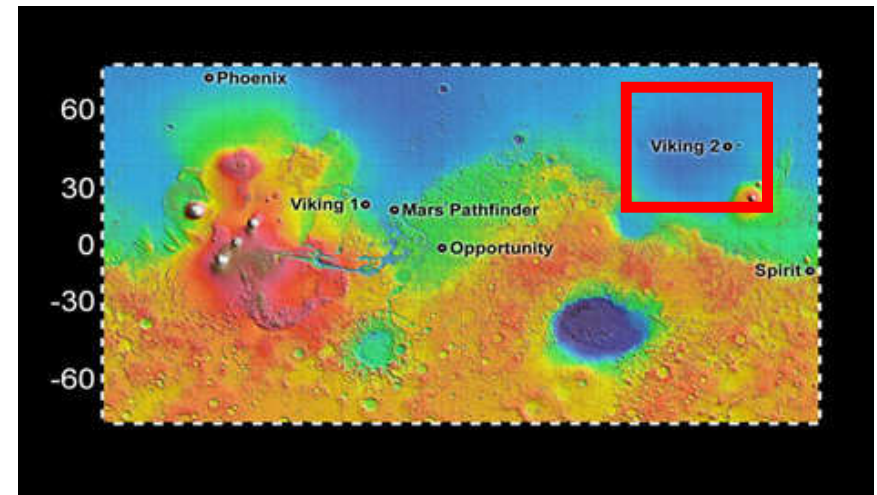
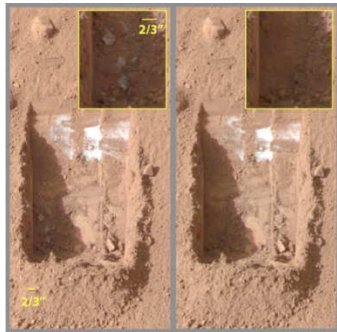
# Subsurface ice

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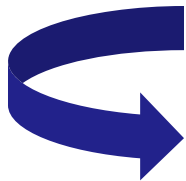
## 1. Phoenix landing site.



Not great for human exploration, though, due to winter CO<sub>2</sub> ice coverage.



## 2. Mid-latitude ice (near Viking Lander 2).



### Evidence for ice

- 1) Surface Morphology
- 2) Excavated icy craters
- 3) Gamma Ray Spectrometer (GRS) data
- 4) Numerical modeling





# Surface Morphology

## Polygonal Ground

**Polygons in polar regions on Earth are evidence of subsurface ground ice.**

University Valley, Antarctica

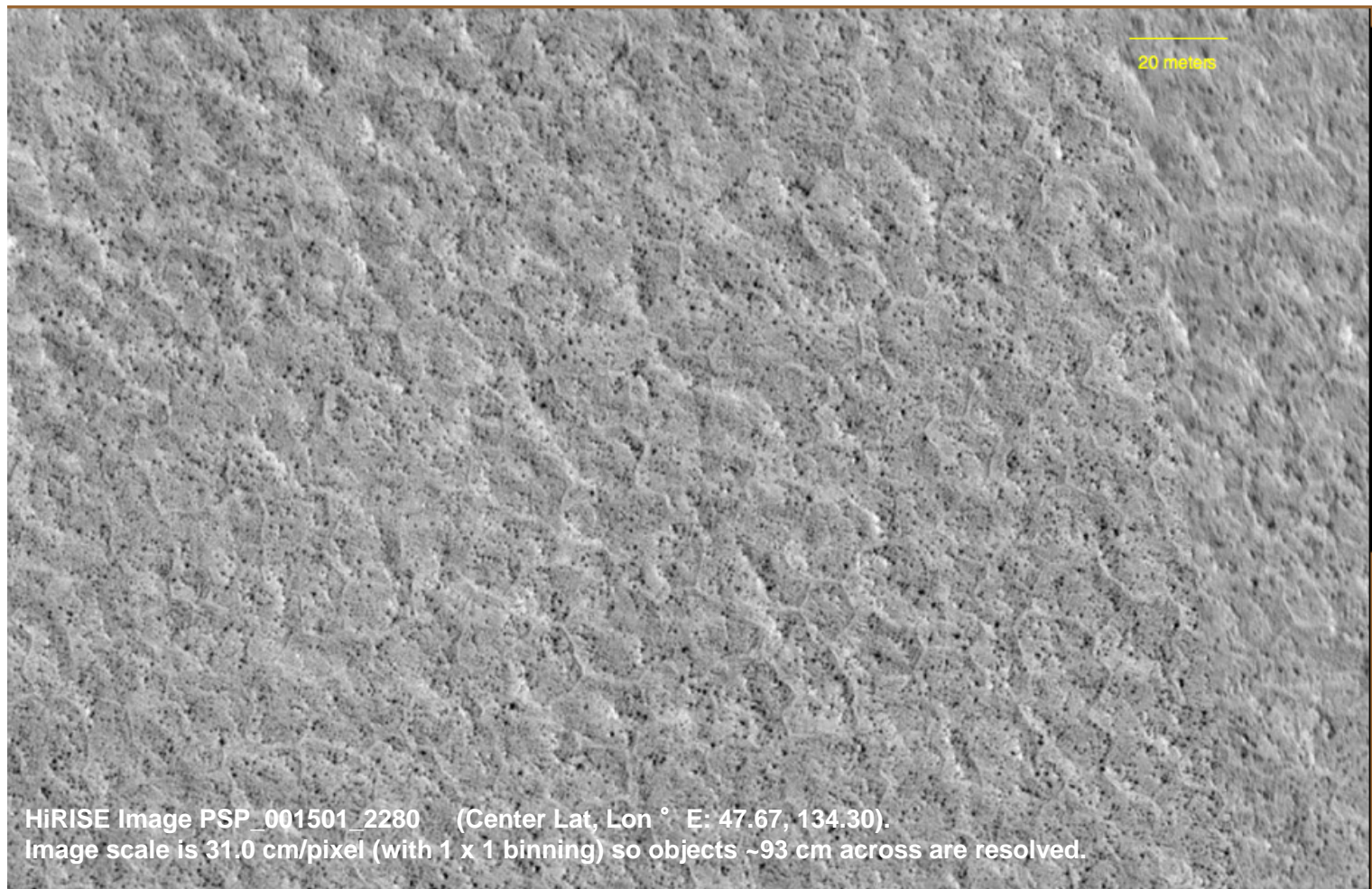




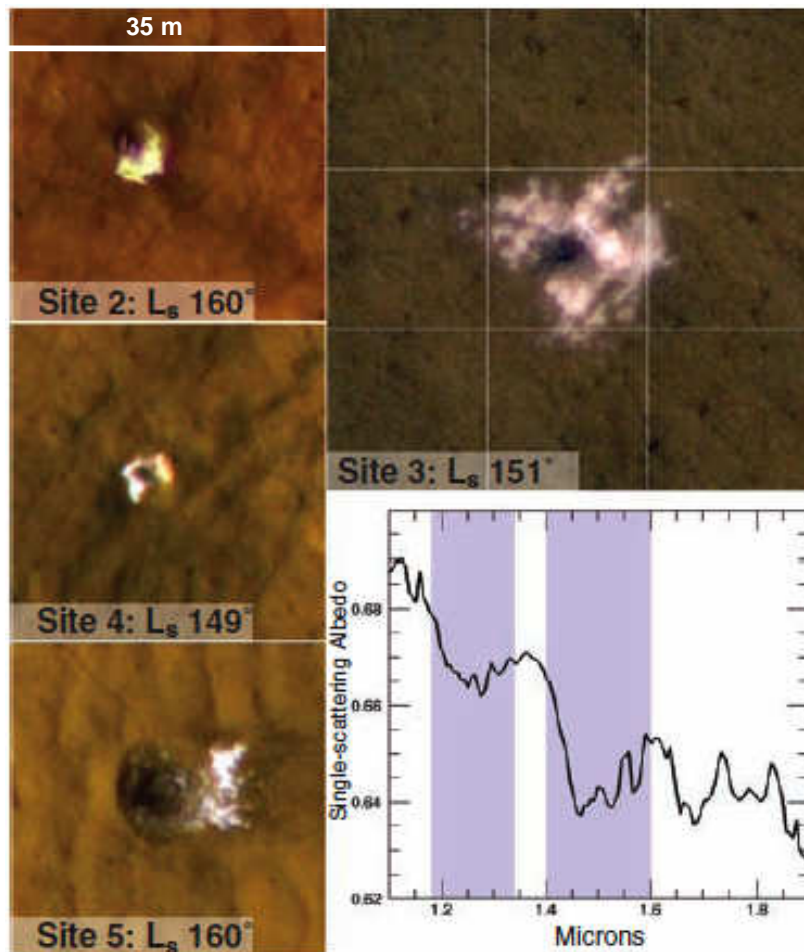
# Surface Morphology

## Polygonal Ground

Polygons observed near VL2 (HiRISE) are evidence of subsurface ground ice.



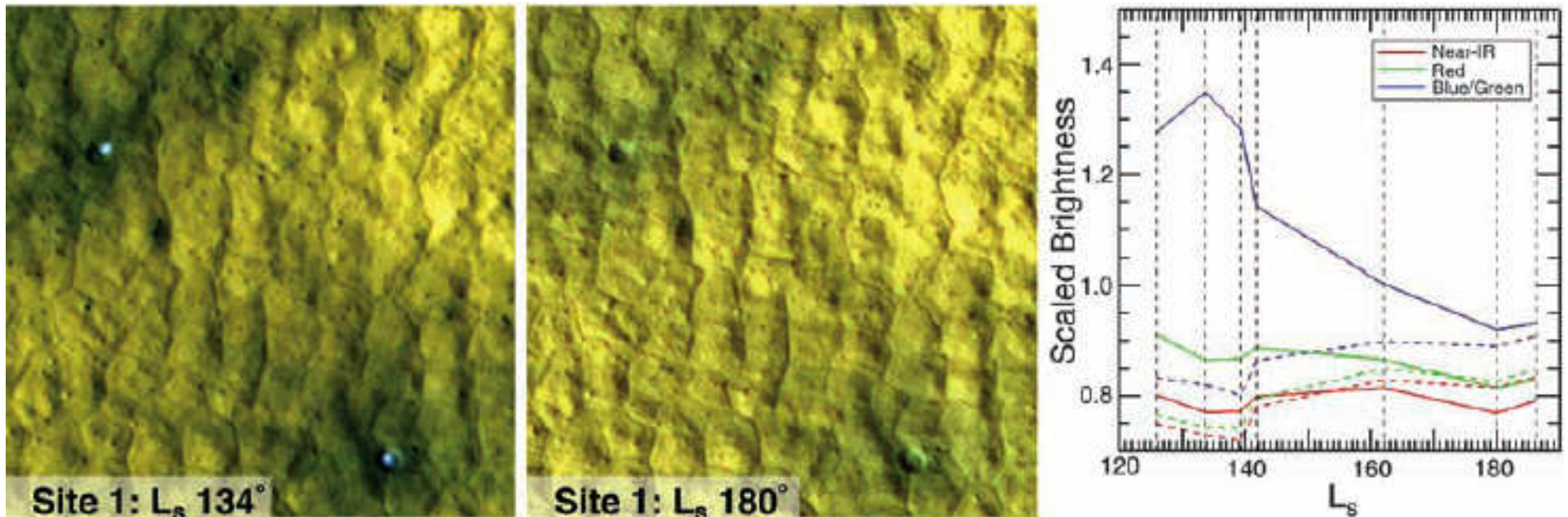
# Excavated Icy Craters



**HiRISE** false-color image data showing icy material excavated by impact craters.

**CRISM** spectra showing water ice bands (highlighted in purple).

# Excavated Icy Craters



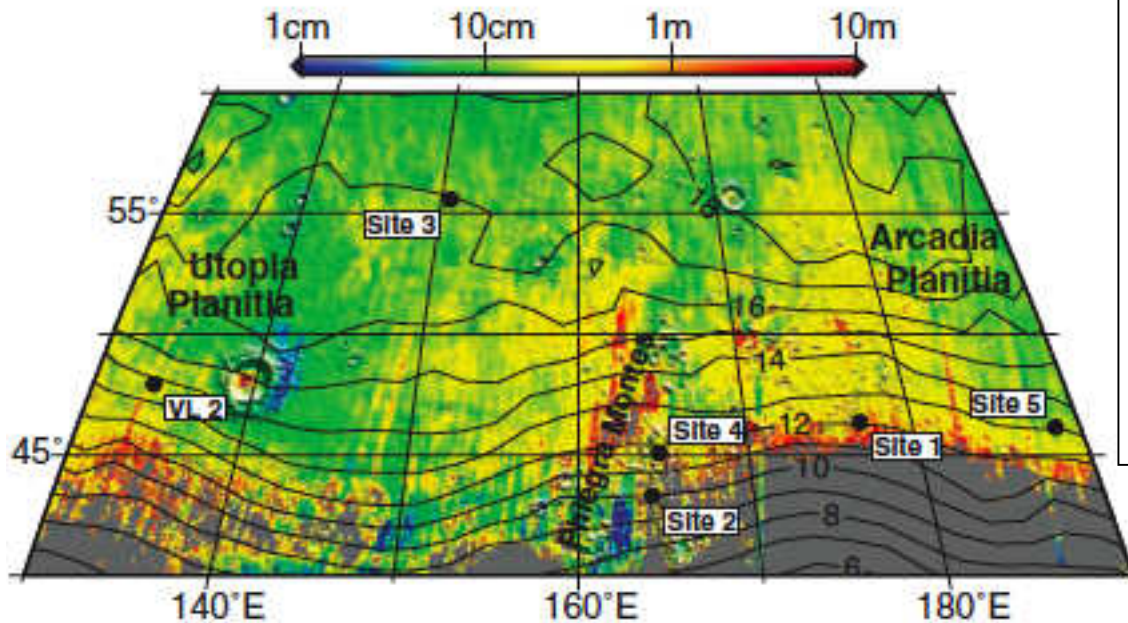
HiRISE false color image data showing disappearance of icy material within fresh craters.



Byrne et al. 2009, Distribution of mid-latitude ground ice on Mars from new impact craters, Science 325, 1674, doi:10.1126/science.1175307.



# Excavated Icy Craters



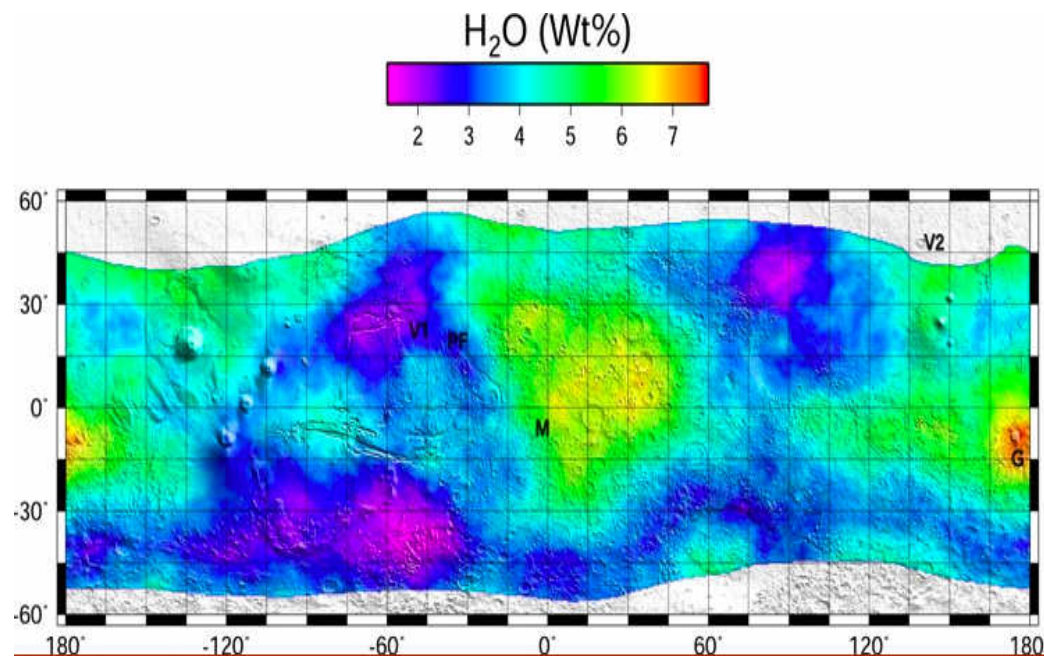
The depth of these impact craters ranges from 0.42 – 2.46 m, so relatively pure ice exists in the upper few meters of the subsurface in these locations.

Viking Lander 2 (VL 2) and locations of crater-excavated near-surface ice (Sites 1-5) are labeled and expected ice depths shown.



Byrne et al. 2009, Distribution of mid-latitude ground ice on Mars from new impact craters, Science 325, 1674, doi:10.10126/science.1175307.

# Gamma Ray Spectrometer (GRS) Data



Mars equivalent weight water based on Mars Odyssey Gamma Ray Spectrometer (GRS) data.

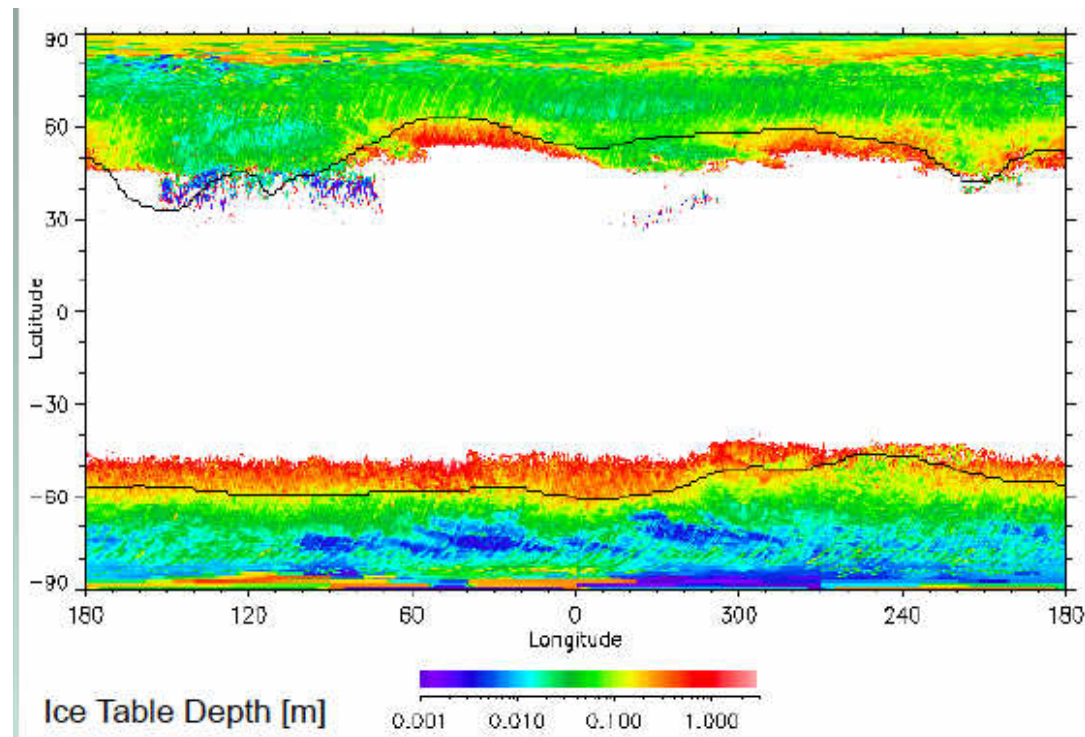
The white sections at the top and bottom of the map represent regions of the planet with high hydrogen concentration due to large amounts of buried water ice ([grs.lpl.arizona.edu](http://grs.lpl.arizona.edu)).





# Numerical Modeling

Numerical modeling predicts the geographic location and depth of near-surface ground ice. This modeling agrees remarkably well with the GRS data.



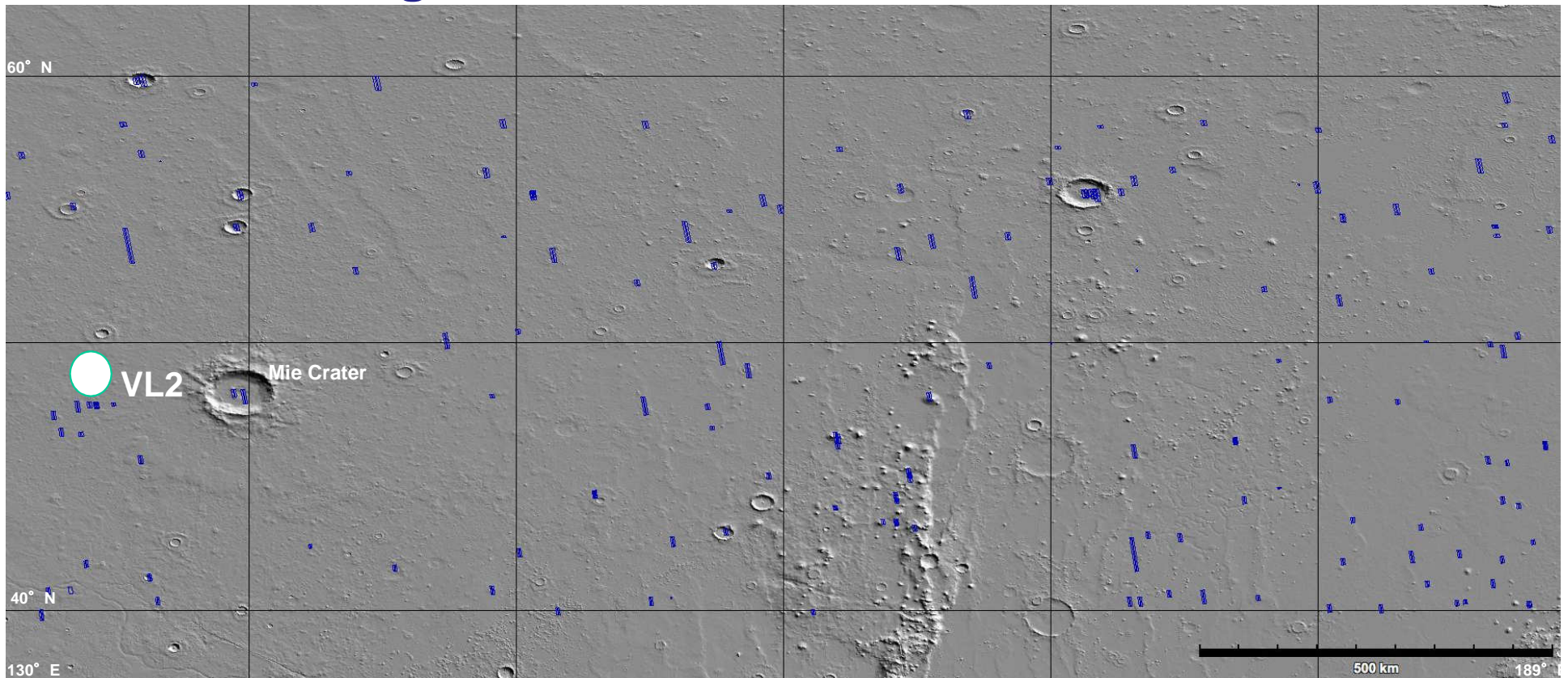
e.g., Mellon et al. 1993; 2004; 2006



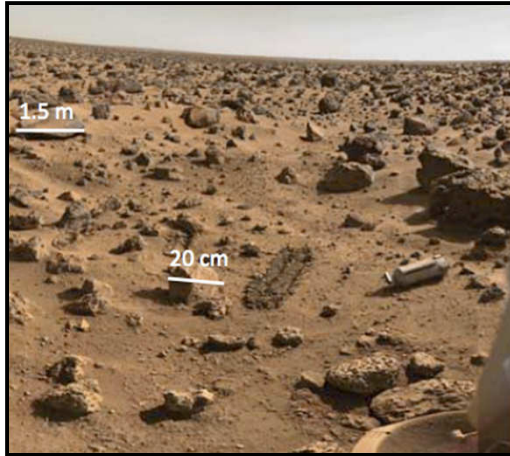
# Region of Interest (ROI)

ROI spans latitude =  $40^{\circ}$  -  $60^{\circ}$  N, longitude =  $130^{\circ}$  -  $190^{\circ}$  E (Byrne et al. 2009 range)

## HiRISE coverage



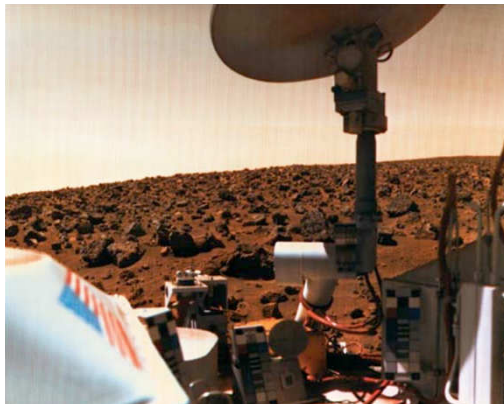
# Viking Lander 2 Site Baseline



The Viking Lander 2 (VL2) landed successfully at  $48^{\circ}$  N and  $135^{\circ}$  E, about 200 km west of the crater Mie in Utopia Planitia.

From the VL2 ground images (left) we see that there are many rocks and the ground is relatively flat.

Polygons are seen in images from orbit, along with other evidence indicative of subsurface ice.



**We use the VL2 site as a baseline in our landing site selection.**

# Landing Site Criteria

Each HiRISE image was divided into 4 equal sections due to large image sizes.  
Each section was rated in comparison with the VL2 site based on the presence of the following:

## Polygons

- Likely indicator of subsurface ice.

## Rough topography

- Landing hazards such as uneven topography, large slopes, bumps, cracks, cliffs, etc.

## Rock Density

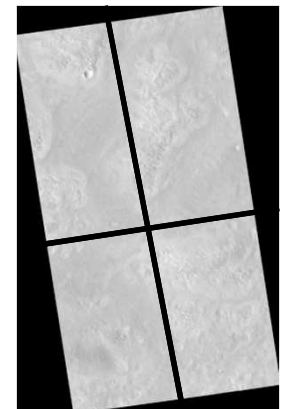
- Rated in comparison with the VL2 site.

## Boulders

- Possible landing hazard.

## Craters

- Possible landing hazard.



PSP\_001435\_2280\_RED

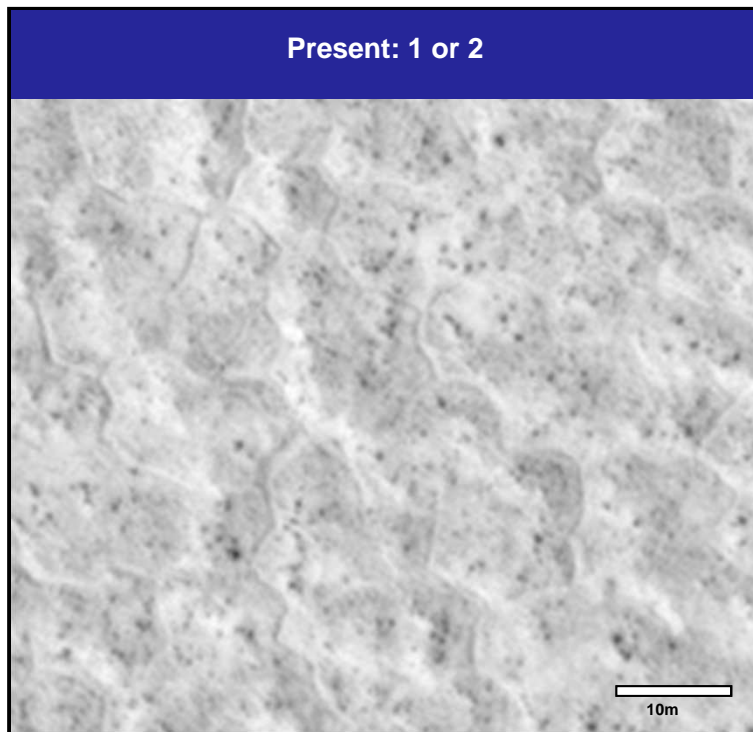




# Polygons

## Polygon Presence (Rated 0-2):

0 = not present, 1 = present but not ubiquitous, 2 = present everywhere



## Polygon Definition (Rated 0-3):

0 = not present, 1 = Large/ defined polygons,  
2 = mix of defined and undefined  
3 = undefined/ weak polygons



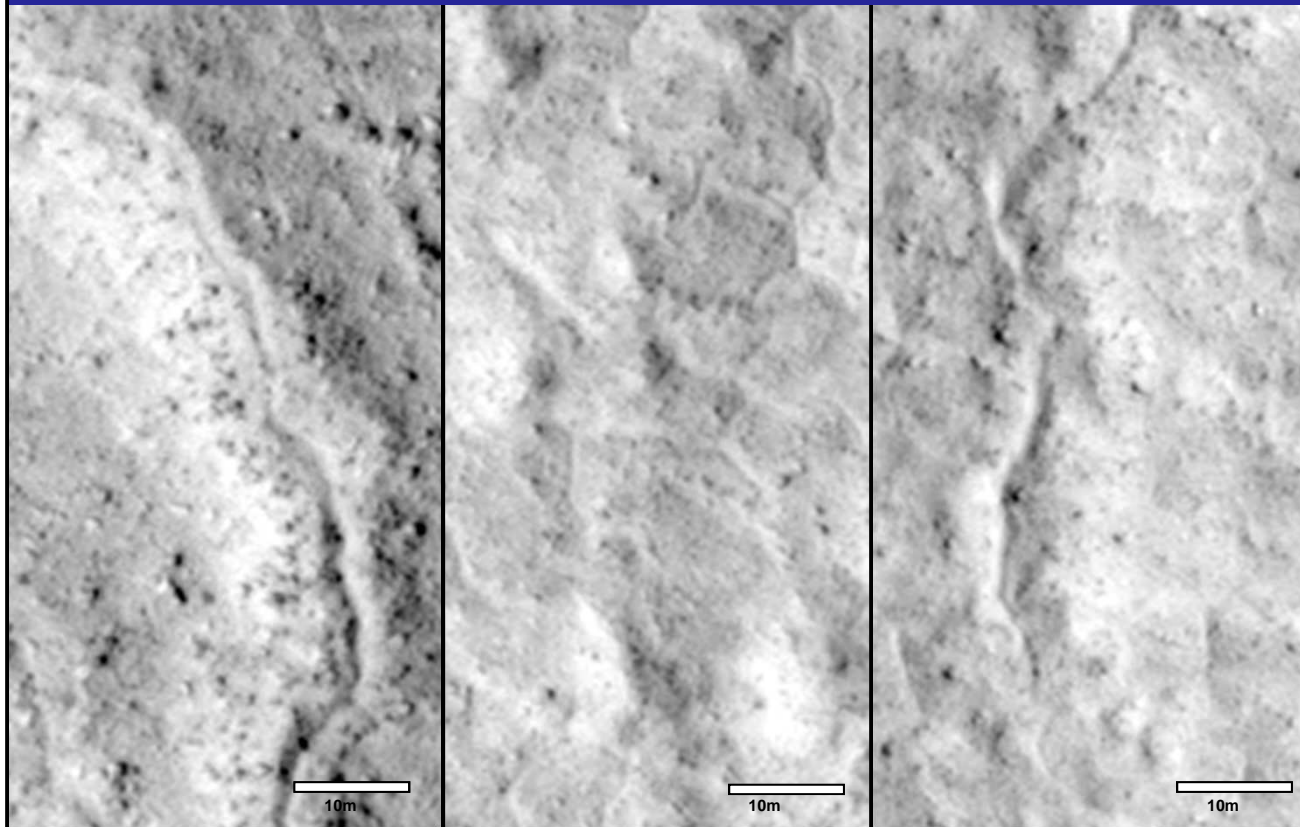


# Rough Topography

**Rated (0-2) where:**

0 = Not rough, 1 = Rough but not covering the entire section, 2 = Rough and ubiquitous

Three examples of rough topography: 1 or 2



Not rough: 0



# Rock Density

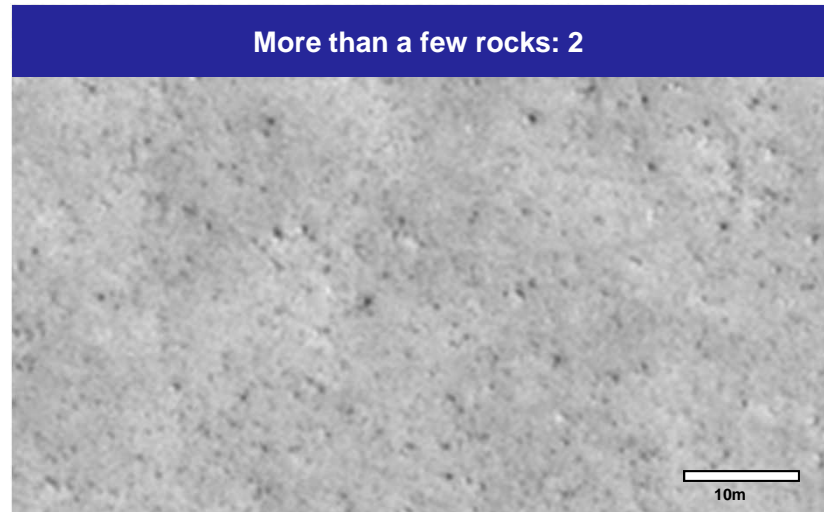
**Rated (0-5) where:**

0 = no rocks, 1 = few rocks, 3 = VL2 rock density, 5 = very dense

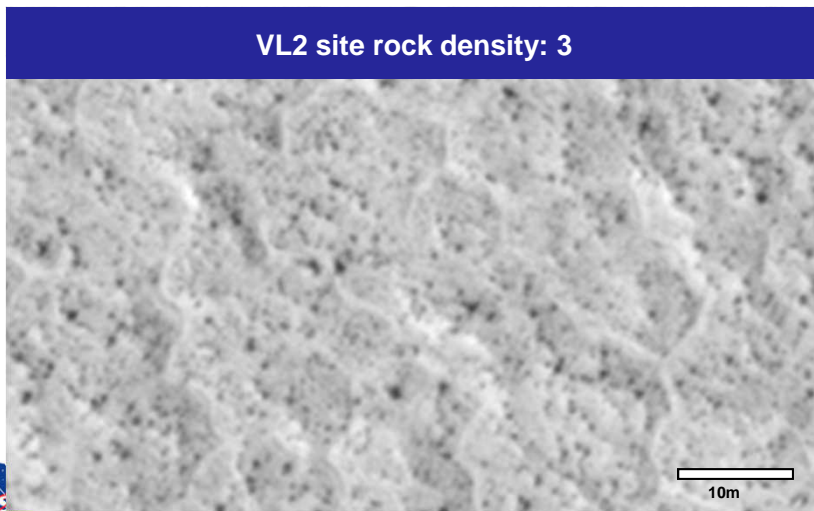
Few rocks: 1



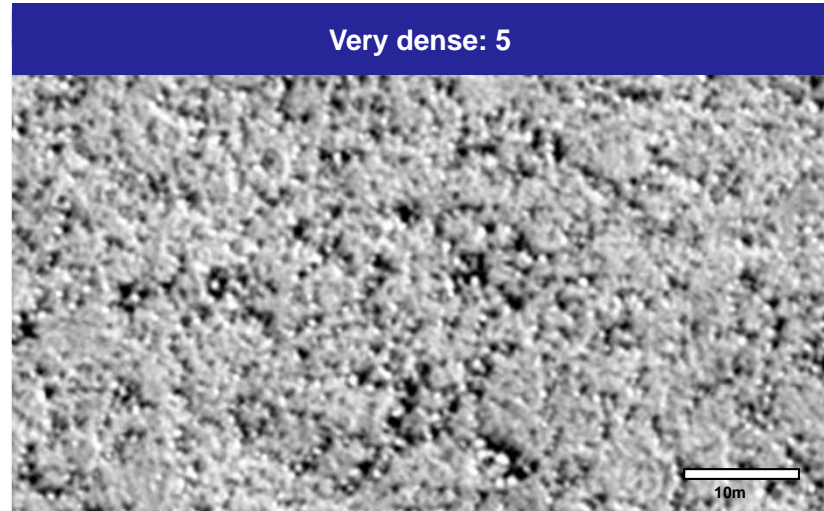
More than a few rocks: 2



VL2 site rock density: 3



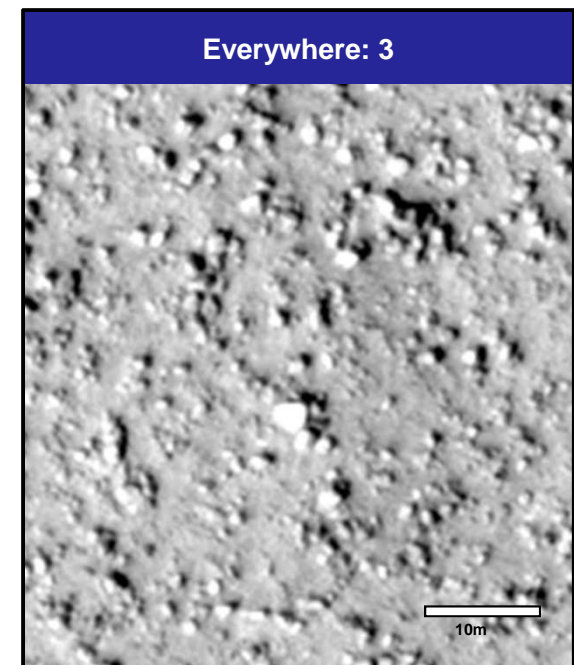
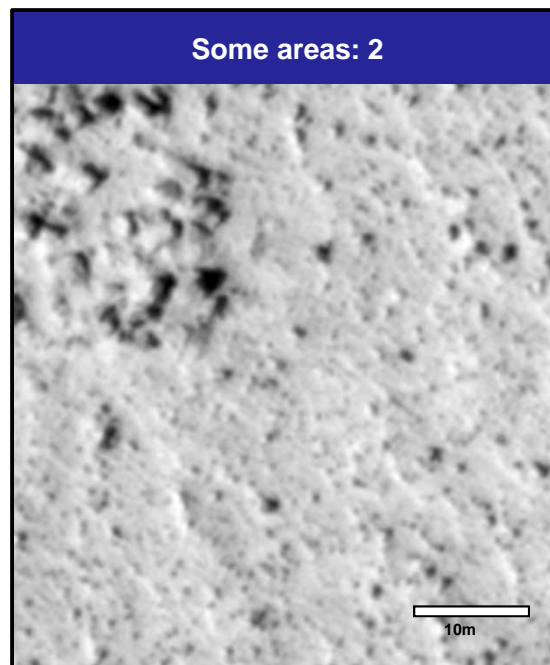
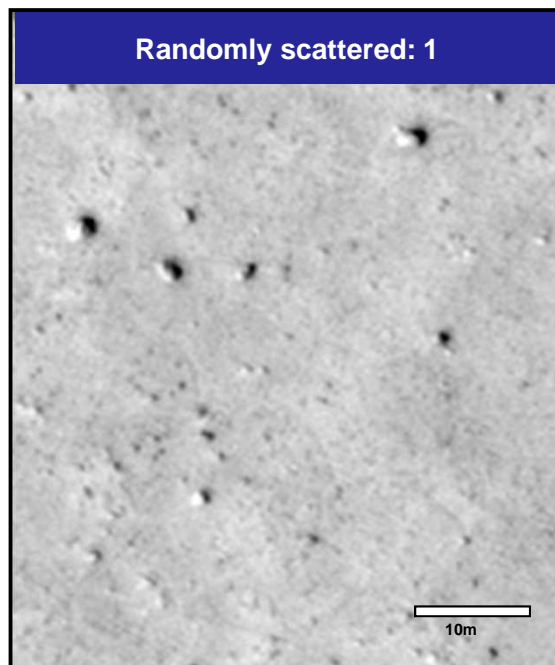
Very dense: 5



# Boulders

**Rated (0-3) where:**

0 = none, 1 = randomly scattered, 2 = concentrated in some areas,

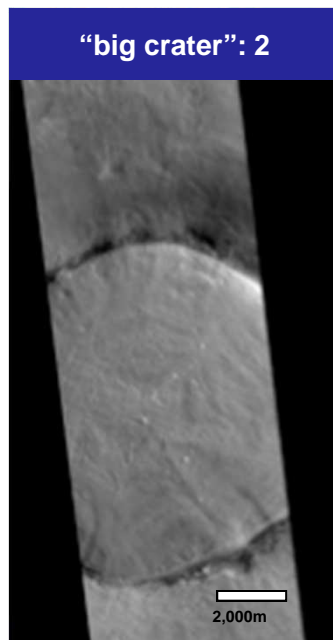


# Craters

Divided into two classes: Big craters covering majority of HiRISE image and small craters interspersed throughout image.

**“Big crater” rated (0-2) where:**

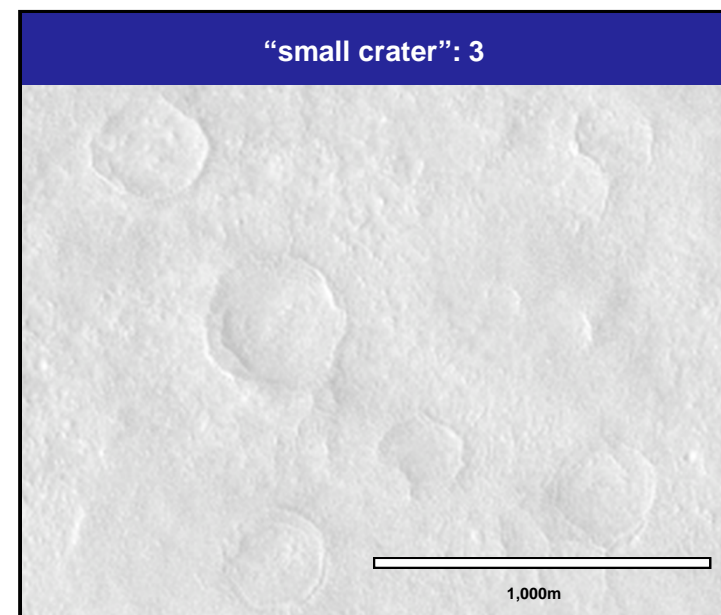
0= no crater, 1= one avoidable crater e.g., only in a portion of the section being rated),  
2= crater present and unavoidable



ESP\_011287\_2165

**“Small crater” rated (0-2) where:**

0= no craters, 1= few 1 or 2  
2= 3 or 4 craters  
3= many craters 5+



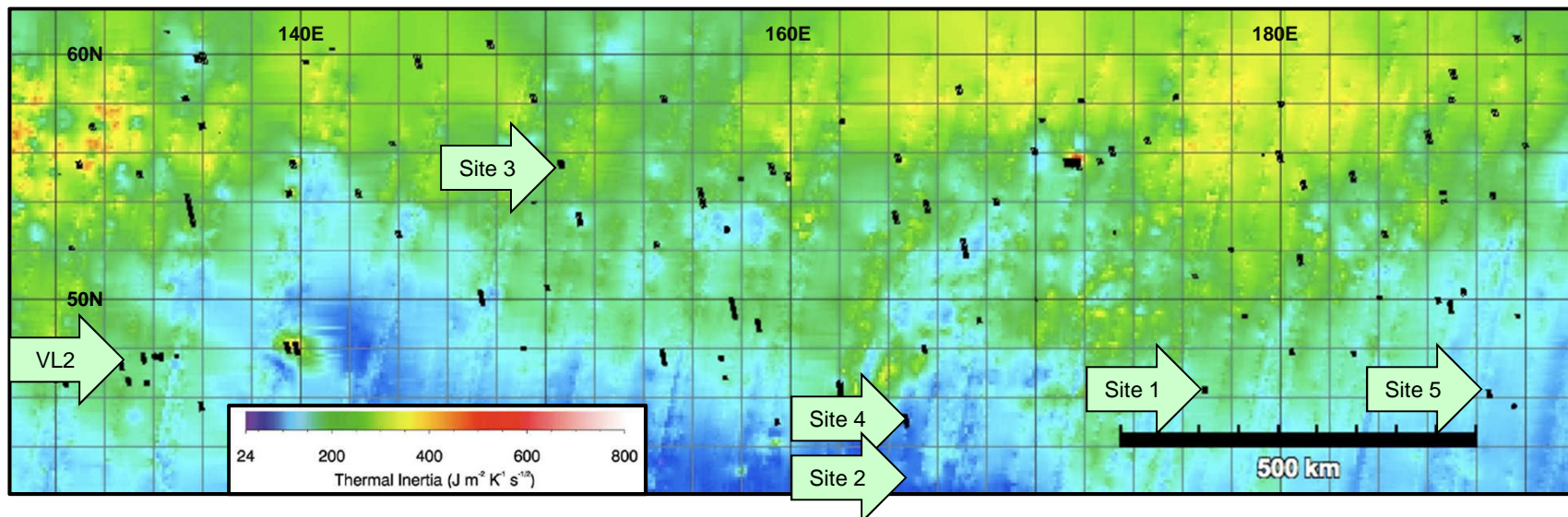
ESP\_016942\_2275\_RED



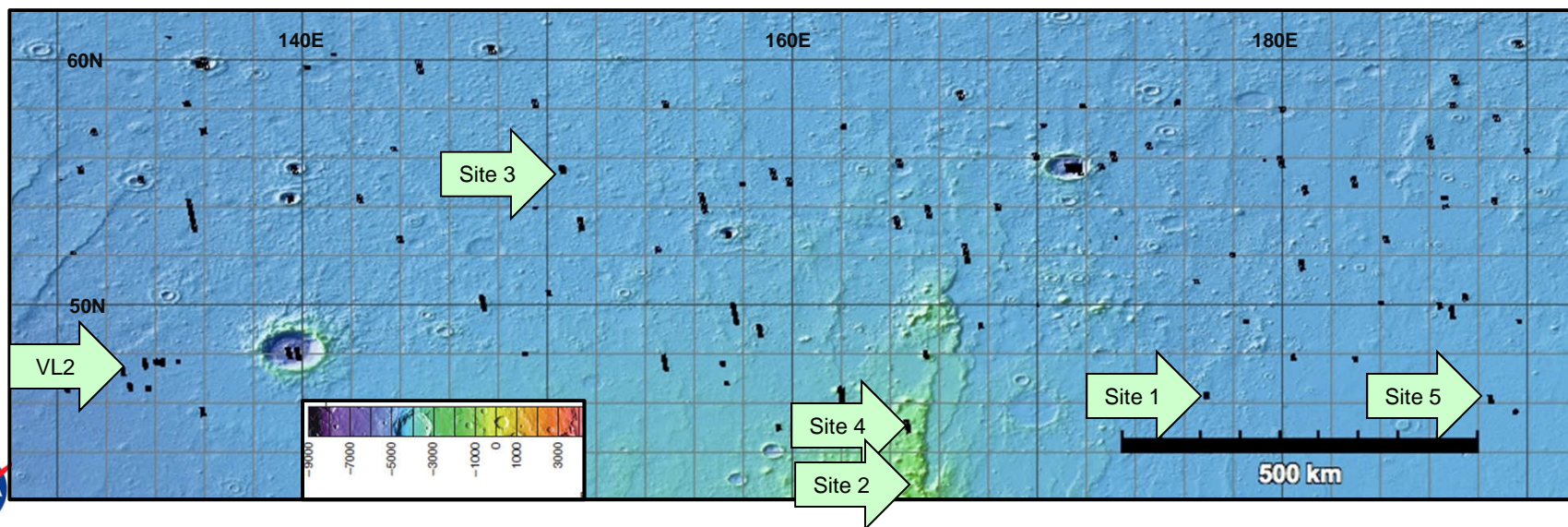


# Icy Crater Sites

TES Thermal Inertial Map, HiRISE images in black (VL2 and Byrne et al. 2009 crater sites labeled)



MOLA Colored Shaded Relief Map





# Site 5

Image: ESP\_011494\_2265

Location: 188.51° E 46.16° N

Model Ice Depth: 0.14m (0.12–0.16)

Polygons: Present and defined

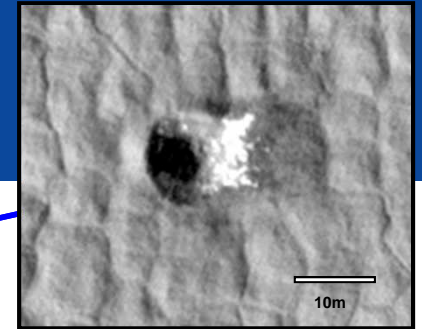
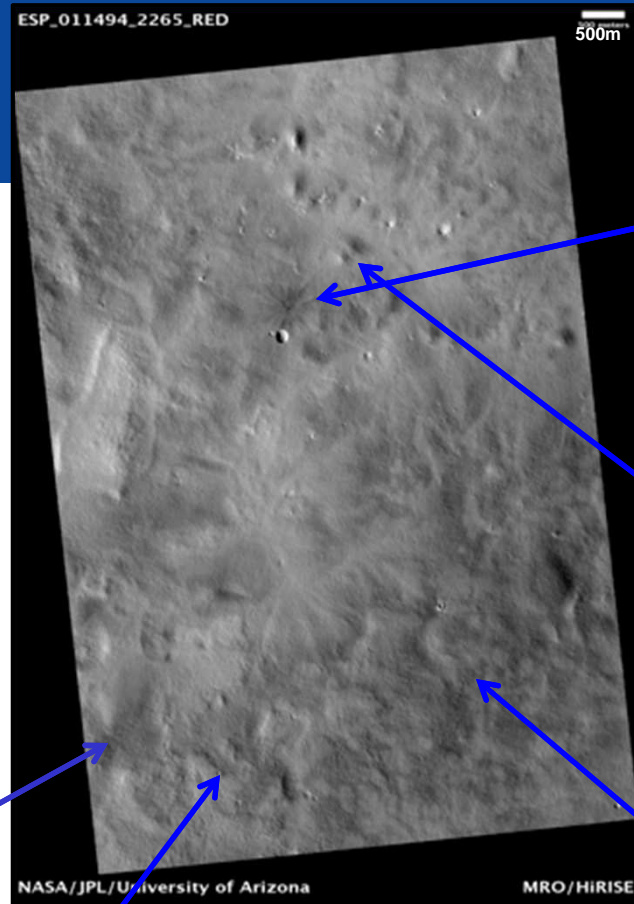
Rock Density: No rocks mostly, 1 or 3 (near uplift) in a few small areas

Topography: Some very small uplift areas, a few cracks around polygons

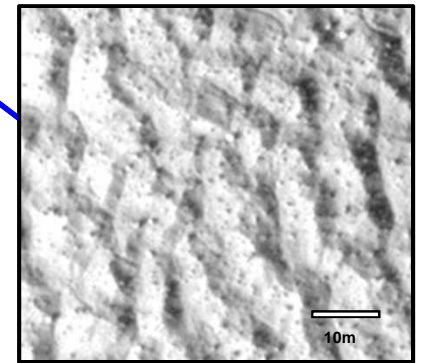
Craters: few small craters in each, more in the bottom right corner

Boulders: none

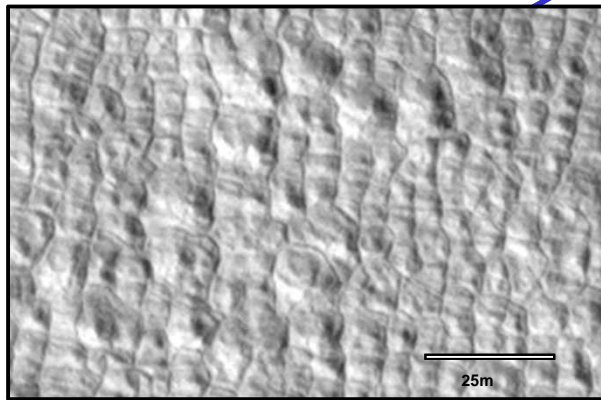
**Excellent site!**



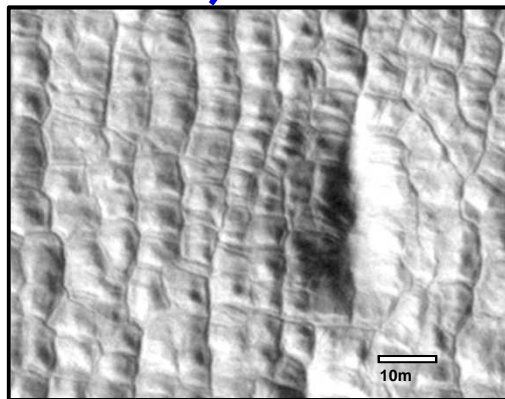
Crater with ice



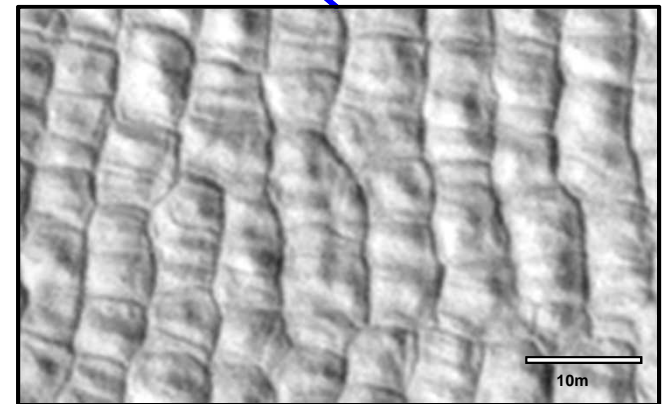
Small area of rock density 3 in the uplift



Small areas of uplift



Cracks around polygons

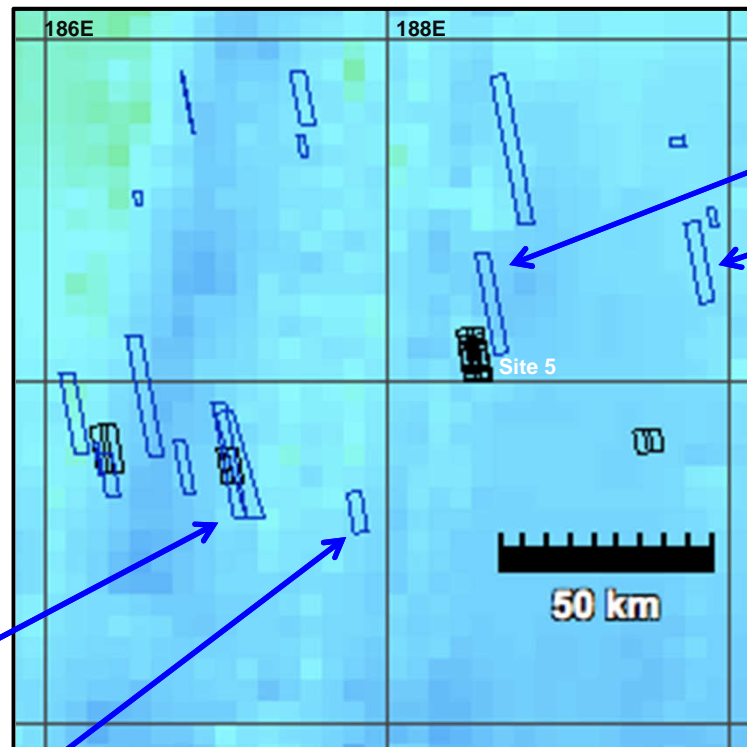


Defined polygons, no rocks

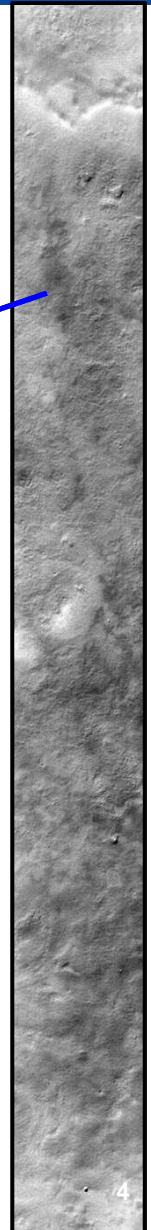
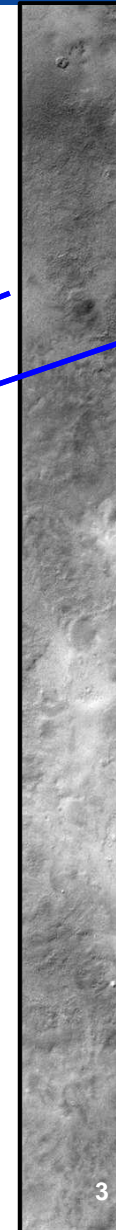
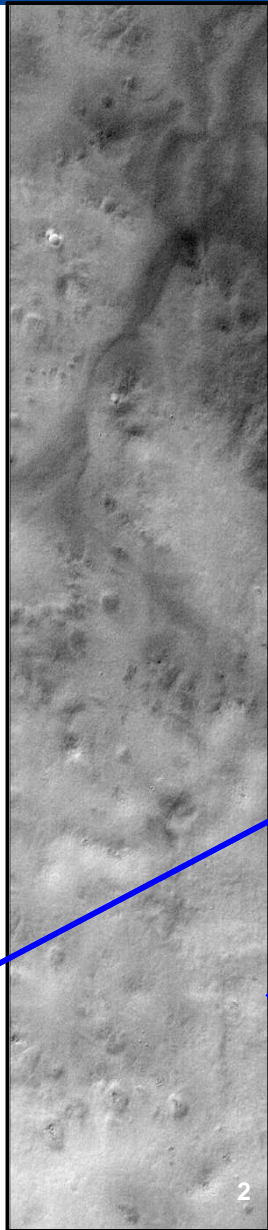


# Site 5

## MOC Narrow Angle

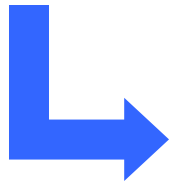


MOC Image Numbers:  
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R0802659  
M0903600  
R1002430



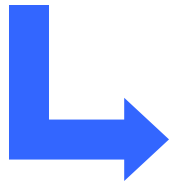
# Conclusions

- **High priority science** can be accomplished through in situ study of martian ground ice.



**Life, habitability, biomolecules, organics, ice formation & stability**

- **Preparation for human exploration** can be accomplished at a site of known ice occurrence.



**Life, biohazards, soil toxicity, characterize water ice for ISRU, landing site certification**

- A viable landing site exists within the VL2 region (fewer landing hazards than VL2 site and observed near-surface ice).



# Backup

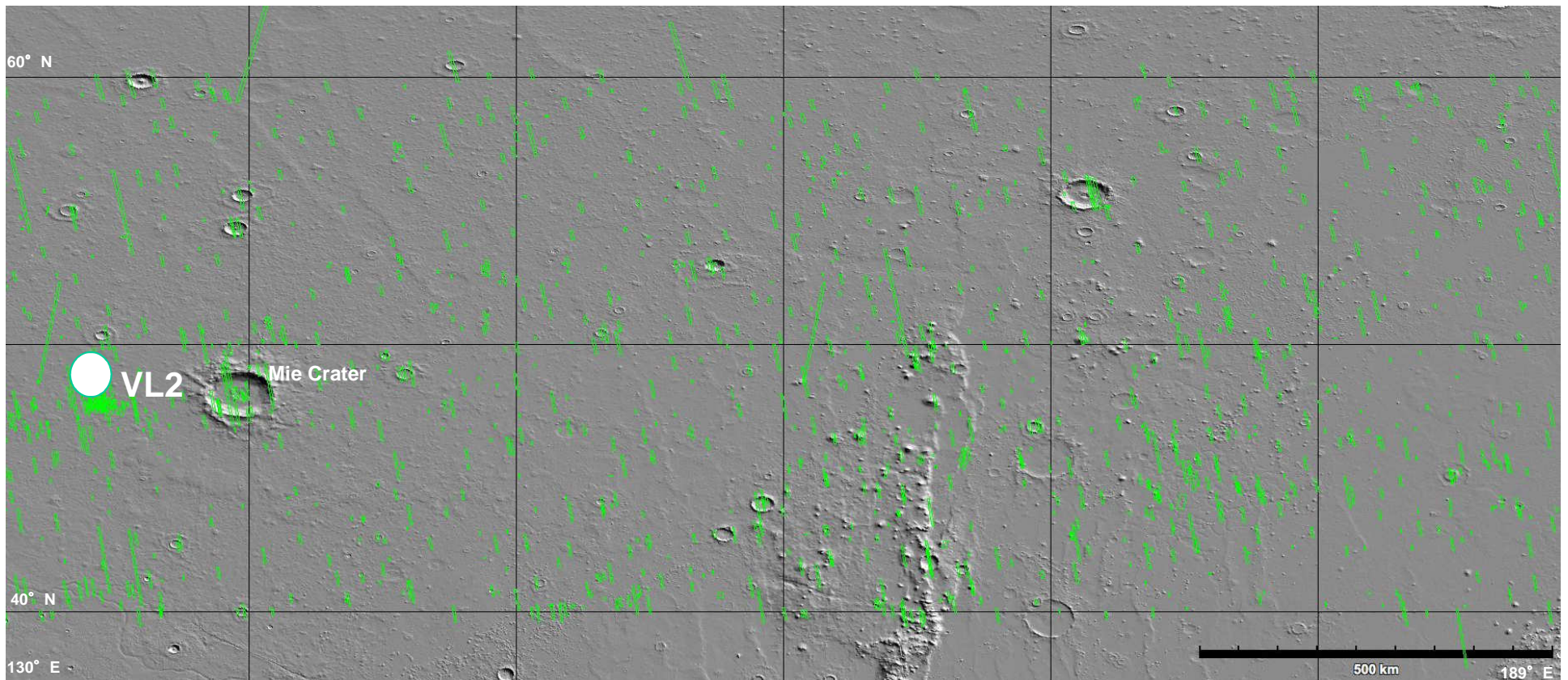




# Backup

## MOC imagery of the Viking Lander 2 Region

MOC: 1236 narrow angle (NA) images from 130-190 E, 40-60 N.



# Access the ice

## **Studies of the ice-rich subsurface on Mars are critical for several reasons:**

The Phoenix mission results have shown that the ice-cemented ground in the northern plains of Mars are likely to be the most recently habitable location on that planet. The near surface ice is a potential source of liquid water when Mars is at high obliquity. The low elevation allows for atmospheric pressure to be above the triple point of water, and the presence of perchlorate suggests a possible redox couple with ferrous iron that could support a chemotrophic metabolism. The discovery of perchlorate at 0.5% in the Martian soil has profound implications for possible life, the search for organics and life, and for human exploration.

## **Examination of subsurface ice can test several hypotheses:**

In summary, the Phoenix landing site on Mars is arguably the most likely site to support recent life on Mars (Stoker et al. 2010). The near-surface ice likely provided adequate water activity during periods of high obliquity. Carbon dioxide and nitrogen is present in the atmosphere, and nitrates may be present in the soil. Perchlorate in the soil together with iron in basaltic rock provides a possible energy source. Furthermore, the presence of organics must once again be considered, as the results of the Viking GCMS are now suspect given the discovery of the thermally reactive perchlorate, and ground-ice provides an ideal substrate to preserve organic molecules for extended periods of time.

